4. The preparatory and emergency use chiefly of the digitalis group of drugs fortifies the heart against these tendencies.

5. Rest, properly timed venesection, and numerous other adjuvant measures are frequently of great therapeutic utility.

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THE ROLE OF THE ELECTROCARDIOGRAM IN PROGNOSIS: A STUDY LIMITED TO HEARTS UNDER SINUS CONTROL AND CONTRACTING AT AN APPROXIMATELY NORMAL RATE.*

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Aid in prognosis has long been sought through an interpretation of graphic records of heart-action currents. The value of a correct diagnosis as a basis for prognosis cannot be questioned. The nature of an arrhythmia can be demonstrated through a study of electrocardiographic curves. Yet the profession has been slow to avail itself of laboratory aids in the diagnosis and prognosis of irregularly beating hearts. Physicians have been even less liable to seek informa-

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tion in regard to those patients whose heart action is regular, especially if the heart-rate is not accelerated. Yet even in the latter group of hearts the electrocardiogram may furnish important information as to the state of the myocardium, information which may be essential to the forming of a correct prognosis. The object of the present paper is to attempt to assess the prognostic value of information derived from the study of electrocardiograms obtained from patients whose hearts were beating under the domination of the normal pacemaker and at a rate which was approximately normal.

Our records were collected in a general hospital in a large industrial city. The patients who were electrocardiographed were nearly all adults; the age incidence varied but the average was probably less high than would be found in many hospitals of the strictly charitable type. Patients were referred to the heart station from various departments in the hospital and by outside physicians, the services of the heart station being equally available to all. The following table indicates the source of the clinical material:

Total number of patients examined	780	
Medical service	480	61.5 per cent.
Gynecologic service	67	8.5 "
Dispensaries	49	6.2 "
Psychopathic service	29	3.7 "
Surgical service	11	1.4 "
Nose and throat service	4	0.5 "
Pediatric service	2	0.25 "
Genito-urinary service	2	0.25 "
Obstetric service	0	0.0 "
Unclassified as to service	80	10.0 "
Outside physicians	56	7.1 "
Number of cases excluded on account of ectopic origin of heart-beat or of rapid rate	220	
Available for purpose of present study	560	

The following abnormalities of the electrocardiogram have been considered.

1. Such distortions of the primary ventricular complex as are usually associated with conduction defects below the bifurcation of the main bundle.

2. Decreased amplitude of primary ventricular deflection as existing in the absence of other marked distortion of the electrocardiogram.

3. Prolonged P–R interval.

4. Invert T_1.

5. Alternation of heart action currents or of the strength of pulse-waves as registered upon the electrocardiographic plate by means of a special device.

We fully recognize the limitations imposed upon us by the nature of the material studied: in spite of these limitations we believe that the study has not been entirely fruitless. The method carried with

it at least one definite advantage—the elimination of the element of expectant attention.

I. Distortions of the primary ventricular complex have recently been the subject of careful study.

Oppenheimer and Rothschild[1] have called attention to the frequent association of certain definite peculiarities of the *Q–R–S* deflections with a group of clinical conditions—arteriosclerosis, coronary artery disease, syphilis—which are liable to be accompanied by degenerative changes in the heart muscle. These authors made postmortem studies of the hearts of 14 patients from whom electrocardiograms showing distortion of *Q–R–S* deflections of a special type had been obtained during life. Disseminated sclerosis which predominated in the endocardial and subendocardial layers was found in all but one; the prognosis in the presence of the described distortion of the electrocardiogram was believed to be grave.

The electrocardiogram which these authors believed associated characteristically with this type of myocardial involvement (which results in "disturbed intraventricular conduction") is described as follows:

1. Abnormal prolongation of the time interval of the *Q–R–S* group beyond the normal limit of 0.1 second.
2. Notching of the *R* wave.
3. Occasional low amplitude of the waves in all leads.
4. Absence of the typical diaphasic curves, with large T_1 waves, as found in experimental branch bundle block.[2]

Carter[2] concludes that "the presence of a predominant sclerosis of the terminal arborizations of the Purkinje system gives rise to electrocardiographic curves of low amplitude associated with a bizarre ventricular complex of a definite type. Curves of large amplitude, essentially diphasic, may justly be regarded from experimental evidence available, as indicative of a definite totally obstructive temporary or permanent lesion of one of the branches of the atrioventricular bundle. The presence of curves of low amplitude, so characteristic of a diffuse sclerosis, did not, however, preclude the existence of definitely localized focal lesions involving the main stem and its branches."

Robinson,[3] while accepting the conclusions of Oppenheimer and Rothschild[1] as applicable to a group of cases, has shown that a like distortion of the electrocardiogram may occur occasionally as an expression of what he believes to be temporary functional fatigue.

[1] Electrocardiographic Changes Associated with Myocardial Involvement, Jour. Am. Med. Assn., August 11, 1917, lxix, 429.

[2] Further Observations on the Aberrant Electrocardiogram Associated with Sclerosis of the Atrioventricular Bundle Branches and Their Terminal Arborizations, Arch. Int. Med., September, 1918, xxii, 331.

[3] Significance of Abnormalities in the Form of the Electrocardiogram, Arch. Int. Med., October, 1919, xxiv, 422.

Willius[4] states that arborization block is now generally accepted to indicate disease of the subendocardial myocardium and evidences serious functional cardiac disturbance.

Robinson's hypothesis added to the conclusions of Carter seems to be a fair summary of the present knowledge of block below the bundle of His.

A study of our records has convinced us that it is occasionally impossible to classify distortion of *Q–R–S* by the criteria of Oppenheimer and Rothschild.[1] Borderline records occur in which it is only possible to assign the block to a point below the main stem of the bundle. Furthermore, one cannot always prove that the block arises as the result of histologic lesion. Thus we have been unable to exclude the fatigue element in several of our cases, since some of our patients have presented themselves for examination but once. However, in no case have we noted a return to normal after the distortion of *Q–R–S*.

Our material consists of records of 19 patients, or a total of 3.4 per cent. of the patients with sinus rhythm: 60 per cent. of the patients were males. The average age incidence was fifty-seven; the youngest patient was thirty-five years old. Most of the patients presented the clinical picture of cardiorenal vascular disease. Syphilis is conspicuous by its absence. In only one case was a positive blood Wassermann obtained, this patient having an aortic insufficiency. In 10 cases the Wassermann was negative, as were history and evidence gained by physical examination. No Wassermanns were taken on any of the 8 remaining patients. In none of these was a clinical diagnosis of syphilis made, and in at least 2 of the 8 it is probable that the disease can be almost definitely excluded.

Measurement of serial plates showed that the width of the *Q–R–S* interval varied from time to time, as between 0.10 and 0.14 in one patient and 0.16 and 0.20 in another. However, widening, having once been established in a given case, the *Q–R–S* interval subsequently was never found to decrease below 0.1. The persistence of a given form of distortion, as established by an individual, has been striking at times. The following case is reported as illustrative:

W. H., male, aged seventy-three years. Admitted November 20, 1915, complaining of dizziness, weakness, dyspnea and swelling of the feet. The diagnosis was cardiorenal vascular disease. The patient remained under observation for four years. He died a cardiac death, December 11, 1919. No postmortem could be obtained. Electrocardiographic curves on admission showed subbifurcation block. The accompanying figures show that a change in contour of curves occurred during the first sixteen months, with but little change during the subsequent twenty-one months.

In regard to nearly all of the patients in this group there was

[4] Arborization Block, Arch. Int. Med., April, 1919, xxiii, 431.

sufficient clinical evidence to enable one to make a diagnosis of an underlying cardiosclerosis. That there are exceptions to this rule is shown by the following case:

H. J. M., male, aged fifty-seven years, clerk. Referred by an oculist for relief from headache: no sclerosis of retinal vessels; palpable vessels unusually soft for age; no symptoms referable to heart, which was apparently normal. Blood-pressure, 110–76. The arteriogram showed slight irregularity of the height of the pulse-waves but was otherwise normal; phthalein excretion (intravenous), 78 per cent. in one and a half hours; peridental infection; chronic sinusitis; pulmonary tuberculosis. Of two electrocardiograms taken at an interval of three weeks, both showed subbifurcation block.

The patient was markedly toxic during the period of observation. Unfortunately an opportunity has not arisen to examine him at a time when his heart muscle was carrying a lighter load. It is not impossible that this patient might subsequently have a return to normal contour of electrocardiogram.

Of our 19 patients, 9, or 40.7 per cent., are dead. Of these 6 lived less than four months after block was demonstrated. One died after a period of four years. Two are alive in whom the distortion was noted forty-five and forty-eight months ago.

We believe that the above statistics are confirmatory of the growing belief that a definite deformity of the *Q–R–S* deflections is often associated with extensive myocardial degeneration and that this finding should be sought for as part of routine in the case of patients showing evidence of cardiorenal vascular disease. Prognosis regarding this group of patients, can usually be made by an experienced clinician without laboratory help. However, the routine examination as carried on in a heart station may be of great value by indicating that certain patients should be referred to an internist before subjecting them to operation or discharging them from the hospital. In occasional cases electrocardiographic evidence of myocardial degeneration may occur in the absence of obvious signs of the disorder. It should be remembered that subbifurcation block may occur as a result of a temporary condition, such as overfatigue or toxemia. Consequently, in doubtful cases repeated observations may be essential.

II. Decreased amplitude of primary ventricular deflections may exist in the absence of other distortion of the form of electrocardiogram. There may be considerable variation in the height of the primary complexes in electrocardiograms of normal individuals. Thus, Lewis[5] found that if a series of curves be taken from a number of active students the minimum in the three leads was 1.5, 4 and 2 respectively, while the maximum was 10, 16.5 and 14 scale divisions. The average of 59 students examined was: Lead I, 5.16; Lead II,

[5] Clinical Electrocardiography, London, Shaw, 1913, p. 22-23.

10.32; Lead III, 6.61. Nevertheless, Lewis believes that considerable divergence from what is regarded as normal probably indicates that the heart is abnormal. White[6] states that "not infrequently one finds electrocardiographic evidence of a very weak myocardium in cases with a regular pulse. This is shown by one of two findings, a very low flat *T* wave (when one can rule out digitalis) and a small excursion of all waves in all leads." He concludes that very small deflections in all leads usually indicate a very weak myocardium. Frazer[7] noted, as a result of experimentally induced dilatation of rabbits' hearts, that a diminution of the size of all the waves of *Q–R–S* group was observed in degenerative conditions of the heart muscle. Oppenheimer and Rothschild[1] employed low amplitude of the primary ventricular complex as one of the criteria for recognizing the electrocardiogram which was associated with myocardial involvement with a bad prognosis.

In selecting a standard for sorting of our electrocardiograms, we have accepted ten scale divisions as the average normal. This has been done in full realization that each patient must establish his own normal and that any standard is therefore an artificial one. At most such deductions can be only inferential. Further sources of error may be due to instrumental defects and faulty technic. There was an occasional unexplained variant as illustrated in Fig. 4. In numerous instances the possibility of instrumental defect appears to have been excluded definitely by the fact that control electrocardiograms gave normal deflections. In a small group of patients there existed so striking a parallelism between lower amplitude and increasing myocardial insufficiency that the association could hardly have been accidental in all of them.

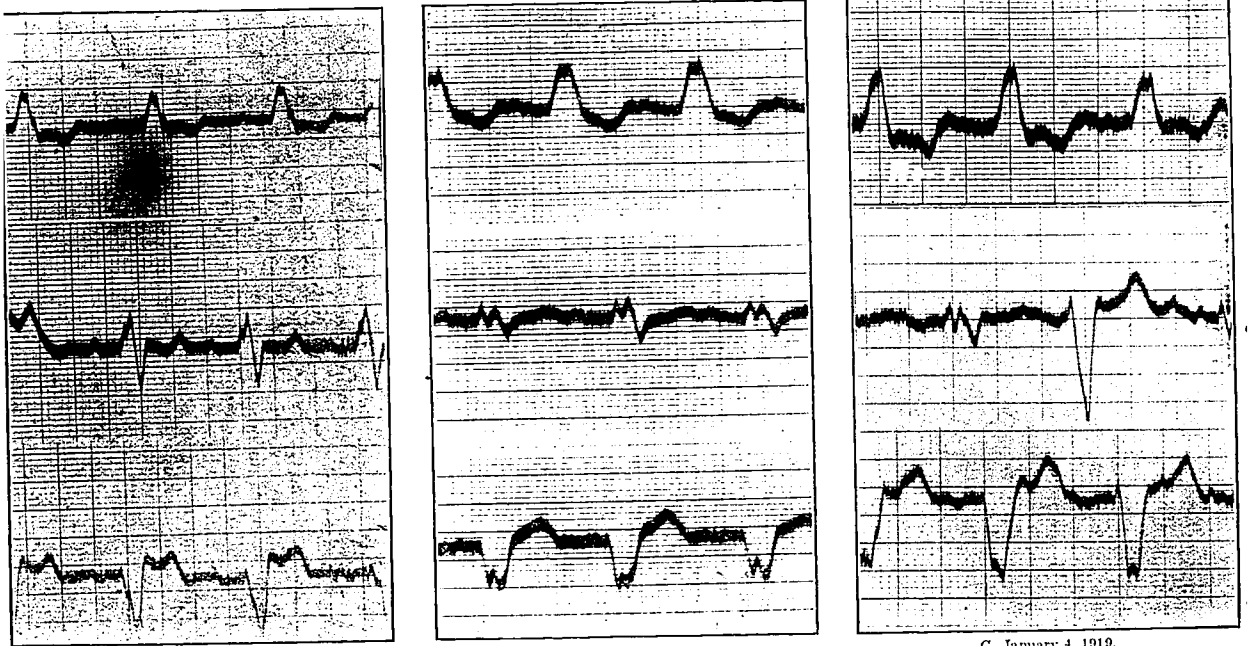
Of our patients, 46, or 5.8 per cent., showed constant or occasional low voltage in all leads; 56 per cent. were females. The age incidence differed widely. The mortality was relatively high: 17, or 36 per cent., are dead. Of the total deaths, 76 per cent. occurred in patients in the fifth decade.

The following case illustrates a changing amplitude exactly parallel to the clinical condition at the time the records were taken. It is believed that the electrocardiograms may be depended upon as each record was checked by control patients.

E. F. D., male, aged twenty-four years, admitted February 3, 1920. Clinical diagnosis; pericardial effusion; at first serous; later purulent. Effusion drained, April 14, 1920. The primary deflection of first electrocardiogram was eight scale divisions. This record was taken at a time when the patient was able to walk about, with apparent comfort. Subsequent curves taken at periods during

[6] Diagnostic Value of Electrocardiography of Hearts Beating Regularly, Med. Clinics of North America, January, 1920, iii, 1035.

[7] Changes in the Electrocardiograms Accompanying Experimental Changes in Rabbits' Hearts, Jour. Exper. Med., September, 1915, xxii, 292.



A. November 27, 1915. *B.* April 17, 1917. *C.* January 4, 1919.

FIG. 1.—Sub-bifurcation block: *B* and *C* are similar, yet a period of twenty-one months intervened. *A* illustrates the difficulty in localizing definitely the seat of the block. It is possible either that the block began in the finer ramifications of the bundle, later extending to the main branch, or that the block occurred in the larger branches from the onset.

which the patient's clinical condition became progressively worse, showed a progressive diminution in amplitude to two scale divisions. A final record taken during a period of improvement after operation showed a return to wider deflections (four scale divisions).

That conclusions based on progressive decrease of amplitude might result in error is exemplified by the following:

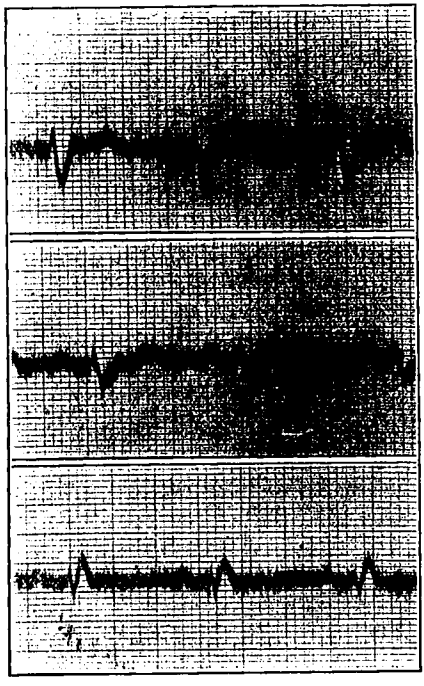
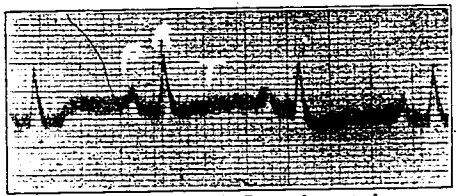
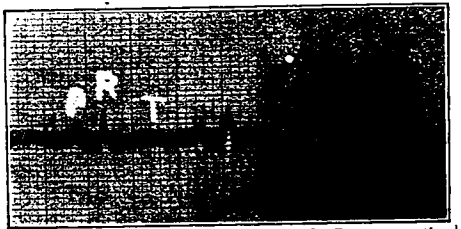


FIG. 2.—Sub-bifurcation block: Occurring in a patient without symptoms, suggesting cardiac disease. H. J. M., aged fifty-seven years. Referred by an oculist for headaches.

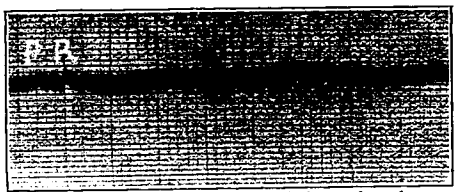
R. G., female, aged seventy-eight years. Admitted May 11, 1916. Clinical diagnosis: acute endocarditis superimposed upon chronic mitral and aortic valvular disease; chronic myocarditis; pulsus alternans. Clinical condition of patient became progressively worse while in the hospital. Electrocardiogram on admission showed normal height of deflections, ten scale divisions, Lead I. Patient



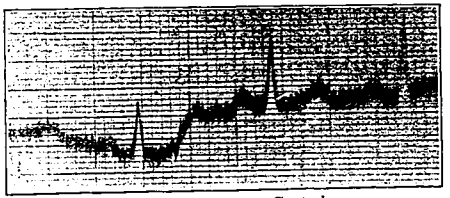
A. February 3, 1920. E. F. D., aged twenty-four years. Serofibrinous pericarditis of tubercular origin; effusion, later becoming purulent. Patient able to walk without dyspnea.



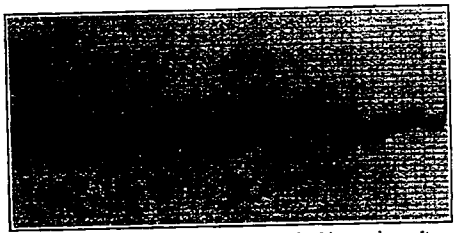
B. March 29, 1920. Effusion more marked. Decompensation severe.



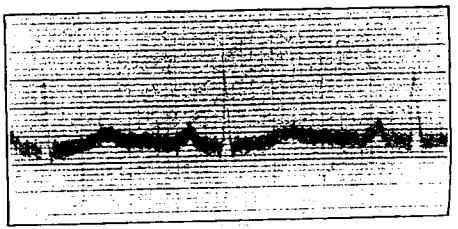
C. April 16, 1920. Forty hours after drainage of pus from peri-

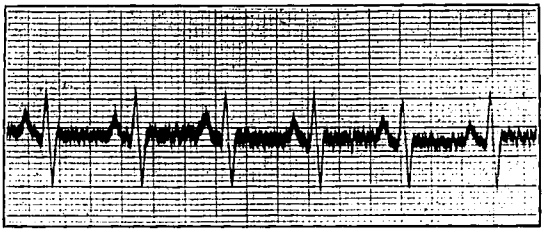


D. April 16, 1920. Control.

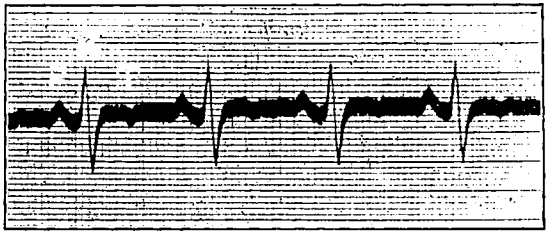


E. April 29, 1920. Increased amplitude thirteen days after operation. Subjective and objective improvement.

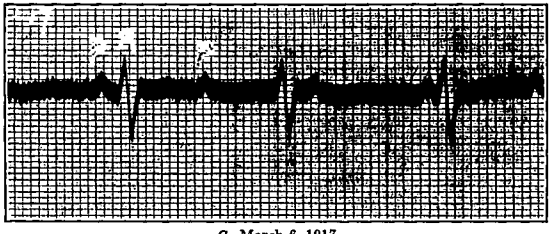




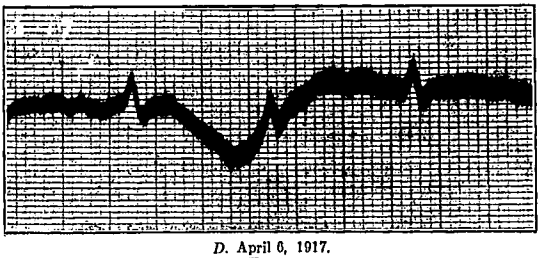
A. June 13, 1916.



B. February 3, 1917.

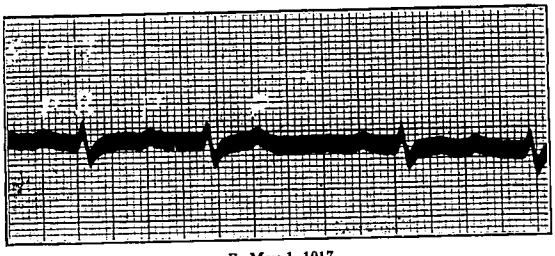


C. March 6, 1917.

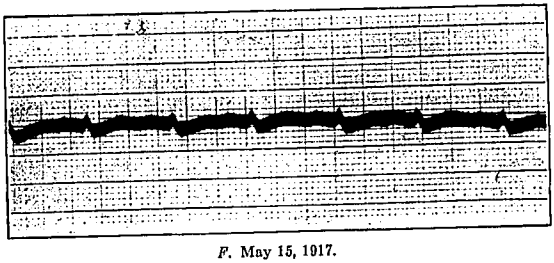


D. April 6, 1917.

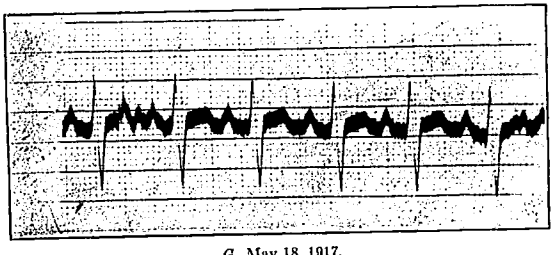
FIG. 4.



E. May 1, 1917.



F. May 15, 1917.

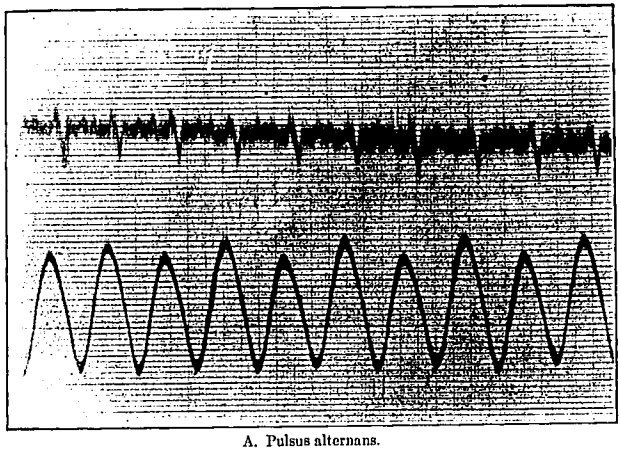


G. May 18, 1917.

FIG. 4a.—Decreased amplitude. Height varying with clinical condition during period of eleven months; sudden return to normal amplitude nineteen days before patient's death and at period when decompensation was profound. R. G., aged seventy-eight years. Acute endocarditis, superimposed upon chronic mitral and aortic valvular disease. Chronic myocarditis; pulsus alternans.

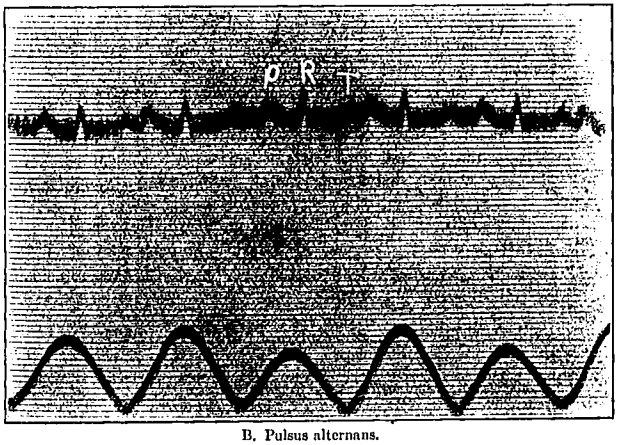
discharged November 2, 1916, no further electrocardiogram being taken. Readmitted January 4, 1917. Patient died June 6, 1917. Patient's clinical condition became progressively worse after second admission. The amplitude of the primary deflections became gradually smaller (from seven to one scale divisions). However,

there was one striking exception; a final electrocardiogram nineteen days before death showed that the deflections had returned to ten scale divisions.



A. Pulsus alternans.

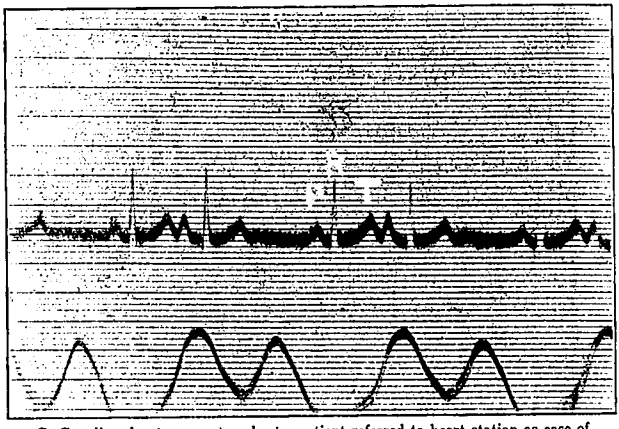
FIG. 5.



B. Pulsus alternans.

FIG. 5a.

III. Prolongation of the *P–R* interval over the normal of 0.2 second may be due to various causes such as acute infections, drug action and degenerative processes affecting heart muscle. There is considerable difference of opinion among observers as to the normal *P–R* interval. Lewis[8] states that "prolongation over 0.20 second is never found in healthy hearts." Hecht[9] regards 0.14 as normal; F. N. Wilson[10] accepts 0.17. Within certain limits each patient sets his own standard. Cohn, Jamieson and Frazer[11] have shown



C. Coupling due to premature beats; patient referred to heart station as case of supposed alternation.

FIG. 6.—Type of tracing obtained by apparatus illustrated in Fig. 7.

that digitalis can prolong the *P–R* interval. Hence unless digitalis influence can be excluded, no conclusions as to prognosis can be based upon prolongation of the *P–R* interval. Such deductions could not be made in patients of our series since regarding most of them no reliable history as to previous medication was available. On the other hand it is exactly in the type of patient in which a prolongation of *P–R* interval might be expected that digitalis is most liable to be administered.

[8] Vide supra, p. 37.

[9] Der Mechanismus der Herzaktion im Kindersalter, seine Physiologie und Pathologie, Ergeb. d. inn. Med. u. Kinderh., Berlin, 1913, ii, 324; quoted by Rupe: Mod. Med., March, 1920, ii, 215.

[10] Recent Progress in Pediatrics, Résumé on the Circulation, Am. Jour. Dis. Children, 1915, x, 376; quoted by Rupe: Loc. cit., p. 215.

[11] The Influence of Digitalis on the T-wave of the Human Electrocardiogram, Jour. Exper. Med., June, 1915, xxi, 593.

IV. Since such inversion is always or nearly always pathologic, according to Lewis[12] inversion of T_1 "is often associated with signs or symptoms of ill omen." This author published figures[13] in which an invert T_1, which followed temporary deformity of primary ventricular complex, became upright when that deformity disappeared. The first curve was taken during a febrile attack, the second, one day later, after the subsidence of fever. Willius[4] states that a close connection exists between inversion of T_1 and disease of myocardium. Cohn[11] and his associates have shown that digitalis can modify T in that a T which was upright in the initial curve may be lowered first and finally inverted. Inversion of T_1 has been noted by White[6] in connection with hypothyroidism the T "tending to become more positive" in the presence of clinical improvement during thyroid feeding. Morrison[14] has noted that changes in the electrocardiogram following bleeding, hot-packs, ingestion of water and fasting may in certain persons affect the form of the electrocardiogram. Harris[15] while admitting that digitalis may affect T_1, draws definite conclusions on inversion of T_1 as observed in 16 of 40 patients electrocardiographed in an out-patient clinic. The cases electrocardiographed were selected on account of dyspnea on exertion, fainting fits and edema. Apparently no history of previous medication was sought, since no mention of absence of digitalization is made in this author's text or accompanying table; yet Harris has the temerity to conclude that "an invert T in the Lead I is reliable evidence of a damaged heart muscle."

Fifty-three cases in our series show inversion of T_1. In 26 of these T_1 was inverted alone. In only 1 case was it possible definitely to rule out digitalis. Hence we are unable to draw any deductions as to the significance of invert T_1 as personally observed.

V. From the standpoint of prognosis, alternation of the pulse, as occurring in hearts beating at an approximately normal rate, is a finding of extreme gravity. Unfortunately the electrocardiograph is capable of recording only the alternation of heart-action currents. The fact that curves showing such a disturbance of mechanism are rare is confirmed by our series in which the finding was present regarding but 0.55 per cent. of all patients examined. It is unfortunate that the electrocardiograph is incapable of demonstrating the disturbance of mechanism underlying the alternating pulse, since the latter finding, if sought for as routine, is found to be of frequent occurrence. Obviously, the value of the string galvanometer would be enhanced if it were possible to record simultaneously

[12] Clinical Electrocardiography, London, Shaw, 1913, p. 28.
[13] Idem, p. 29.
[14] Changes in the Electrocardiogram due Possibly to Alterations in Blood Volume, Proc. Soc. Exper. Biol., and Med., 1916-1917, xix, 64.
[15] Significance of an Inverted "T" in the First Lead of the Cardiogram, Lancet, February, 1919, i, 168.

electrocardiograms and pulse-waves. Our discussion of alternation will be limited to the description of an apparatus which we have devised to fulfil this indication.

The device which we are using combines the simplicity of the cuff method of Herrick[16] with the accuracy of the electrocardiogram. It therefore obviates the various sources of error of the former while preserving much of its simplicity of application. Used by us first only when a sphygmograph was not available, it is now used as routine on all arteriosclerotic patients and on those exhibiting premature contractions. The apparatus which is both time-saving and inexpensive may be visualized by reference to the accompanying illustration (Fig. 7).

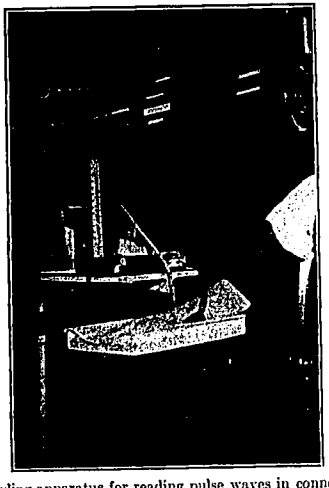


FIG. 7.—Recording apparatus for reading pulse waves in connection with simultaneous electrocardiogram; used for detection of pulsus alternans. *A*, camera; *B*, straw attached to cork float which rides on mercury; *C*, transverse arm of lever, which rests on straw; *D*, upright arm of right-angled lever, which oscillates in front of camera lens.

The oscillations of the mercury column of a sphygmomanometer are transferred to a right-angled lever, the upright arm of which moves in front of the slit of the camera of an electrocardiograph. The cuff of the sphygmomanometer is applied in the usual manner and the tracing is taken at a pressure slightly below that ordinarily accepted as the systolic pressure.

[16] Pulsus Alternans Detected by the Sphygmomanometer, Jour. Am. Med. Assn., February, 1915, lxiv, 739.

We claim no originality in the production of a combined electrocardiogram and pulse-tracing. Methods of producing such combined records abound. It is even quite possible that other investigators have employed the principle upon which our appliance is based. As we have seen no reference in the literature to such an application, however, we feel justified in describing it here. The accompanying figures are illustrative of the results obtained.

Conclusions. 1. Electrocardiographic curves are capable of furnishing important information as to the efficiency of the heart muscle.

2. As cardiac failure is due to myocardial insufficiency the electrocardiograph can furnish information valuable from the standpoint of prognosis.

3. Conduction defects below the bifurcation of the bundle of His may be associated with a characteristic electrocardiogram. It is often difficult to determine whether such defect is in the branch bundle or in the terminal arborization. The defect may be functional or it may be due to histologic change. In the latter case the prognosis is grave.

4. Decreased amplitude of the primary ventricular deflections is at times found to have a striking relationship to clinical evidence of a failing heart. Exceptions to this relationship occur, and, as there are several possible sources of error in obtaining reliable curves, observations should be carefully controlled and definite conclusions withheld until the subject is further elucidated.

5. Prolongation of P–R interval and inversion of T_1 have been associated by various observers with degenerative processes in heart muscle. A prolongation of P–R and an inversion of T_1 can also be brought about by digitalis action, and it is precisely in the class of cases in which information as to the P–R interval and inversion of T_1 could be of value that digitalis is liable to have been administered. Conclusions as to the condition of heart muscle as based on the presence of one or the other of these deformities must be confined to patients from whom digitalis effect can be excluded. Analysis of our series has shown that digitalis effect can seldom be excluded in such patients as are routinely referred to a heart station. Hence, prolongation of P–R and inversion of T_1 are liable to be of little prognostic significance in such patients.

6. A discussion of pulsus alternans does not come properly within the scope of this paper, since the underlying disturbance of mechanism can seldom be demonstrated by the string galvanometer. This fact is unfortunate, since the recognition of an alternating pulse carries with it so grave a prognosis that the search for this finding should be routine in certain classes of patients. A simple device is described whereby galvanometric curves and pulse waves can be simultaneously recorded. This can be done with but little expenditure of time, and the method has therefore become routine in our laboratory.

7. The practical value of laboratory evidence as to the presence of disease of the heart muscle is inversely proportionate to the skill of the attending physician in interpreting clinical evidence as to the imminence or presence of heart failure. Such skill is possessed chiefly by the internist. Yet internists furnished 61.5 per cent. of all cases examined. The statistics of other heart stations would probably be similar. It becomes, therefore, the duty of the internist to instruct members of other branches of the profession regarding the necessity of more frequent use of instruments of precision in the diagnosis and prognosis of disease of heart muscle.

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OBSERVATIONS ON NEGATIVITY OF THE FINAL VENTRICULAR T WAVE OF THE ELECTROCARDIOGRAM.*

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A REVIEW of the literature on electrocardiography, both experimental and clinical, at once reveals a variance in views as to the interpretation of the normal electrocardiogram. The two views that have gained broadest recognition are: (1) All waves are manifestations of excitation and contraction of heart muscle, and (2) the waves result from electric changes accompanying conduction of the impulse and contraction of the muscle.

Einthoven assumed that the right ventricle represents the cardiac base and the left ventricle the apex, and that the dominance of negativity in the right ventricle causes an upward deflection while dominance in the left causes a downward deflection of the galvanometer. Thus the *R* wave is ascribed to contraction of the right heart, the *S* wave to contraction of the left heart and the horizontal *S–T* interval to neutralization of basal and apical negativity. The *T* wave represents contraction of the right ventricular base outlasting that of the left.

Eppinger and Rothberger object to Einthoven's assumption in ascribing the rôle of cardiac base to the relatively weak right ventricle and regarding the left ventricle with its massive muscle bulk as the apex.

The views of Kraus and Nicolai are based on the structural arrangement of the ventricular musculature into systems. Follow-

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